APPLICATIONS OF BAR CODE TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

A Special Research Problem

Presented to

The Faculty of the School of Civil Engineering

Georgia Institute of Technology

THESIS
G8338

by

William George Grip

In Partial Fulfillment

of the Requirements for the Degree of

Master of Science in Civil Engineering

GEORGIA INSTITUTE OF TECHNOLOGY
A UNIT OF THE UNIVERSITY SYSTEM OF GEORGIA
SCHOOL OF CIVIL ENGINEERING
ATLANTA, GEORGIA 30332

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TABLE OF CONTENTS

Page

LIST OF FIGURES..... iv

LIST OF TABLES..... v

CHAPTER 1 INTRODUCTION

1.1 Introduction..... 1

1.2 Objective..... 5

1.3 Methodology..... 6

CHAPTER 2 BACKGROUND

2.1 Construction Industry Applications..... 7

2.1.1 Designer Applications..... 7

2.1.2 Fabricator/Supplier Applications..... 10

2.1.3 Construction Field Applications..... 14

2.2 Bar Code Material Selection & Testing..... 25

2.3 Successful Uses of Bar Code Technology..... 34

CHAPTER 3 IMPLEMENTATION PLAN FOR BAR CODE USE IN CONSTRUCTION

3.1 Introduction..... 44

3.2 Labor Hours..... 46

3.3 Construction Equipment Costs and Utilization.... 53

3.4 Document Control..... 65

3.5 Material Control..... 71

3.6 Acquisition Strategy..... 77

CHAPTER 4 SUMMARY..... 81

CHAPTER 5 CONCLUSION..... 83

CHAPTER 6 RECOMMENDATIONS..... 87

REFERENCES..... 89

BIBLIOGRAPHY..... 91

LIST OF FIGURES

FIGURE #	TITLE	PAGE
1	Typical Bar Code Symbol.....	2
2	Portion of a Drawing Title Block....	8
3	Portion of Material Takeoff Menu Tablet	11
4	Structural Steel Beam Bar Code Label	17
5	GHCC Manual System.....	35
6	GHCC Bar Code System.....	37
7	Typical Slot Scanner.....	52
8	Typical Location Code.....	57
9	Typical PDTs.....	63

LIST OF TABLES

TABLE #	TITLE	PAGE
1	Relative Label Environmental Suitability.	27
2	Bar Code Label Considerations.....	29-30
3	Bar Code Marking Technologies.....	31-33
4	Typical Document Types.....	70
5	Bar Code Equipment Costs.....	79-80

CHAPTER 1

1.1 INTRODUCTION

Bar coding is a proven method utilized to enter information rapidly into a computer system. This technology has been in use for over fifteen years in the manufacturing and retail industries. It utilizes a series of wide and narrow bands and spaces to represent the information it wishes to convey to the user. A typical bar code symbol is shown in Figure 1. The size and distribution of the bands combined with the spacing and size of the light bars determines the type of bar code symbology employed (Blakely 90). Most codes can be read from either direction by means of a bar code reader, wand or scanner. These devices can be connected to a computer directly or store data for future download if used in a portable capacity. Further, the readers can and do use a variety of different technologies, from moving beams, which can read bar codes from up to eighteen inches away, to light pens, which must be in contact with the bar code to read it.

The standard in the automotive, defense and manufacturing industries is known as Code 39 or Logistics Applications of Automated Marking and Reading Symbols (LOGMARS). Code 39 allows the use of both letters and numbers in the data field. Although no standards exist in the construction industry, those Construction Industry Institute (CII)



Figure 1

Typical Bar Code Symbol

(Blakely 90)

member firms that have implemented bar code technology have utilized Code 39 symbology.

As in any American industry, the construction industry has many requirements for data gathering and entry. It is estimated that thirty percent of the cost of a typical data processing operation can be attributed to data gathering and data entry (Bell-Gillis 89). Typical applications of data processing may include material inventory control, project scheduling, labor time cards, drawing review and monitoring, tool issue and control and equipment control.

The primary reason for implementation of a bar code system is to reduce the cost of this data processing function. Other benefits include :

1) Rapid entry of data - While a skilled typist can enter characters at a rate of two to five per second, bar coded information can be entered at a rate of up to thirty characters per second.

2) Use of unskilled labor for data entry - Minimal training is required to teach a person to operate a bar code scanner.

3) Minimization of errors - Data from bar codes is essentially error free, compared to the one error in three hundred in a manual entry situation.

4) Facilitation of remote data entry - Data can be obtained using portable units in out-of-the-way locations, eliminating manual recording and, later, manual entry into the computer system, at an estimated time savings of thirty to sixty percent.

5) Consolidation of events - Data collection and direct entry into the computer system are achieved with one movement of the reading device.

6) Inexpensive and available - Bar code technology can be implemented quickly and inexpensively, through a variety of vendors, and completely compatible with the existing computer system.

1.2 OBJECTIVE

The objective of this research is to investigate the applications of bar code technology in the Construction Industry. To achieve the objective, this research will:

1) Review in detail, bar code applications and technologies currently in use,

2) Investigate label materials available for bar coding as they apply to construction use and provide a mechanism for selecting the proper label material type,

3) Review and critique at least three uses of bar code technology in the construction/facilities area, and

4) Formulate an implementation plan for the use of bar code technology on military construction contracts within the Naval Facilities Engineering Command.

1.3 METHODOLOGY

Chapter 2 will discuss current and potential bar code uses in the construction, as well as, construction related industries. Additionally, Chapter 2 will address a methodology for selecting the proper bar code label material for construction uses and detail three documented cases of successful use of bar code technology by construction/facility related operations. Chapter 3 will propose an implementation plan to encourage private sector, as well as Federal Government, involvement in the development of bar code use in the construction industry. Chapter 4 will summarize the important points made previously in this presentation. Chapter 5 will present conclusions centered on the construction recent efforts to implement bar code technology and some thought towards what can be done to stimulate increased interest in bar coding. Chapter 6 will conclude this presentation with specific recommendations directed toward securing a place in the contractor's daily operation for bar code technology.

CHAPTER 2

BACKGROUND

2.1 CONSTRUCTION INDUSTRY APPLICATIONS

Bar coding applications related to the construction industry can be divided into three distinctive areas :

1) Designer Applications
2) Fabricator / Supplier Applications
3) Construction Field Applications

2.1.1 Designer Applications

Bar codes can be used to facilitate information flow with respect to both drawing revisions and notes (Rasdorf-Herbert 90). Revisions to drawings, whether major or minor in nature, can cause problems to shop personnel, fabricators, designers, engineers, and management if they are not properly updated. The use of bar codes, installed on each drawing which specifically indentifies it, can alleviate these problems by providing a drawing inventory and status system accessible directly as a part of the firm's, or project's, management information system. Figure 2 shows a portion of a drawing title block. Drawing history, including revisions, can be accessed by scanning the bar code while connected to the data base. Bar codes can be especially useful if the number of revisions made are

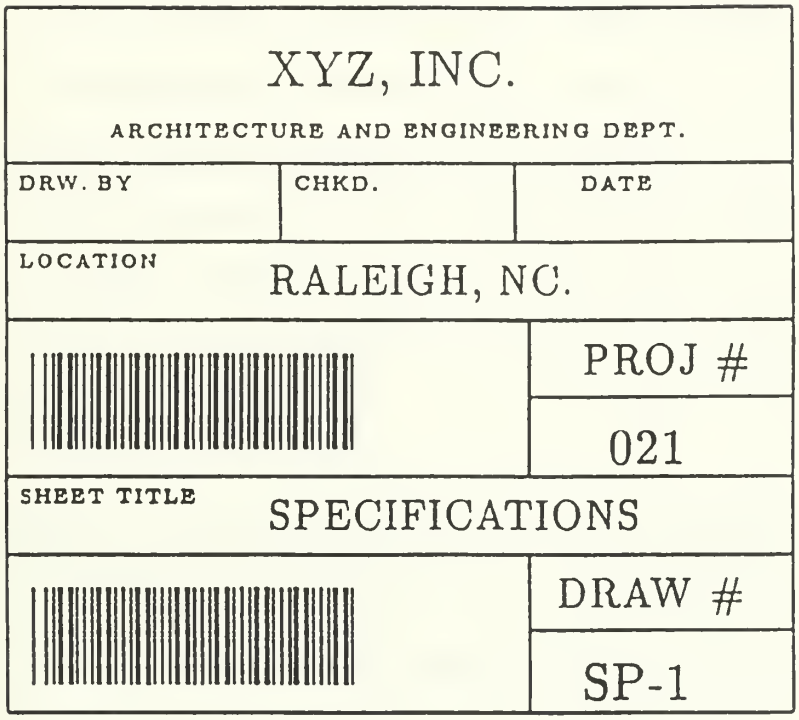


Figure 2

Portion Of A Drawing Title Block

(Rasdorf/Herbert 90)

in excess of the space typically allocated in the drawing's revision block for manual entry. Bar codes can also be useful for incorporation of notes on a project drawing. These notes can provide a more detailed source of information to the user in the way of installation guidelines and material requirements. While this method will not replace the voluminous specification which normally accompanies the drawings, it will help to un-clutter the drawing for better readability and allow for an increase in the information conveyed compared to the notes typically incorporated on the drawings.

Another designer related application of bar coding involves the review of contract submittals and quantity takeoff. By attaching a bar code, a quick scan of the submittal can by provide the submittal's status, what further action is required and when it will be complete. Quantity takeoff can be accomplished with the implementation of short bar codes which identify the type of material, its unit acquisition cost and its unit installation cost. The short codes would be listed on a menu tablet, perhaps by trade function or Construction Specification Institute (CSI) grouping, in a manner best suited to the individual estimator. Though this system cannot replace the manual determination of how much material is required, it will eliminate the need for handwritten lists and manual keyboard entry of data, if

utilizing a computer takeoff software, which many companies now do.

As an illustration of bar code use in the quantity takeoff evolution, the following summary of a pilot program is provided. A CII engineering contractor has developed a comprehensive personal computer (PC) based system for piping material takeoff (Bell-Gillis 89). The contractor loaded a 25,000 item material list to the PC's hard disk and developed a bar code menu tablet to be used with the existing quantity takeoff software. A portion of the quantity takeoff menu tablet is shown in Figure 3. Data was entered using a portable data terminal (PDT) programmed to permit scanning of the bar codes. The estimator entered the contract number and general descriptive information (area, service, etc.) and then used the menu tablet to enter the material code, size and quantity. The contractor utilized this system on the quantity takeoff for a $400 million project and recovered the costs associated with the system development and training (150 man-hours) in the time saved over having to perform the takeoff on approximately 10,000 items manually.

2.1.2 Fabricator/Supplier Applications

Fabricators and suppliers use technology to control the availability of materials needed in production, the issue of

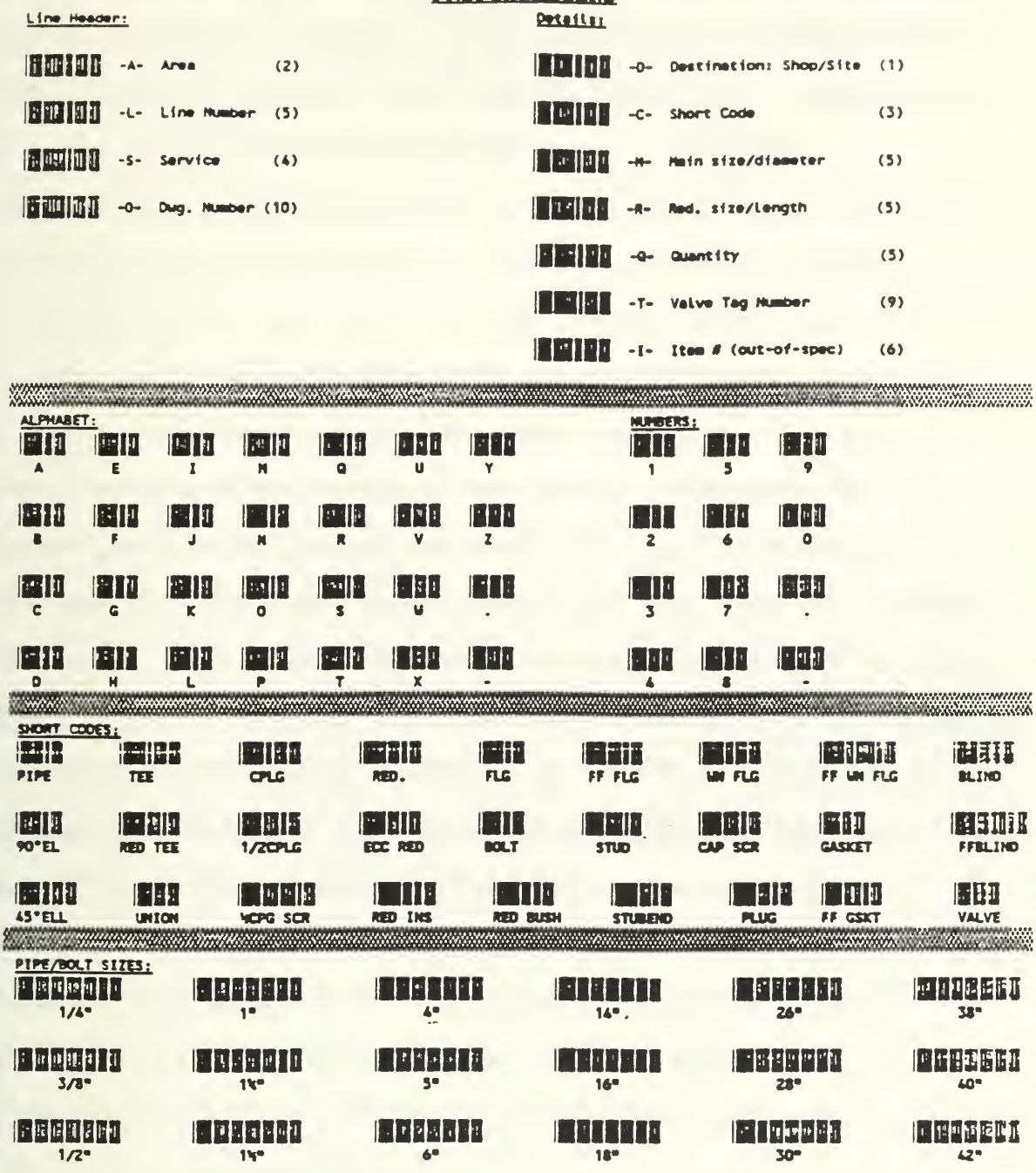


Figure 3

Portion Of Material Takeoff

Menu Tablet

(Bell/Gillis 89)

tools, the shop floor process and the inventory and shipment of the completed product to the purchaser. General Dynamics Land Systems Division Detroit Army Tank Plant, which builds M-1 and M-60 tanks for the Department of Defense, implemented a system known as the Automated Tool Inventory Control and Tracking System (ATICTS). Under ATICTS, workers would draw tools and consumables from bins after the tool's bar code and employee's identification (ID) badge (which contained a bar code) were scanned. The process was reversed upon return of the tool. According to Tom Reese, senior manufacturing engineer, the implementation of the bar code system has benefited the operation in a number of ways. " We have increased service to the plant by being more efficient at the (tool) window and by providing more detailed disbursement information. Because materials are charged to the customer when they are issued from the crib, detailed disbursement tracking also helps us meet our ' perfect charging ' goal ", he explained. Mr. Reese added, " We've also had a reduction of emergency stock items, from seven to ten per day to one to two per week. This is an indication that we have much better control of our inventory " (Ryan 87).

Producto Machine Company of Bridgeport, Connecticut, utilizes bar coding to track the processing of work orders. A work order number, quantity and sequence of operations are bar coded on every order (Ryan 87). Upon receipt, the

worker would log his/her ID number into the system and then enter the work order number by scanning the bar code on the accompanying paperwork. Upon completion of the work order, the worker would log the ID and work order number out of the system. Not only did the system provide a method of tracking material, but it allowed for a production of work order history (movement from operation to operation) and an analysis of worker productivity. The entire system paid for itself in eighteen months, reduced accounting and data processing costs by twenty five percent, reduced key inventories by eighteen percent and improved the accuracy and timeliness of related reports (Ryan 87).

Inventory and shipping concerns can also be addressed by bar coding. Materials, upon receipt, are barcoded before they are directed towards the storage area. The bar code labels not only contain information about the product, such as receipt date and description, but also pinpoint the storage location. Fullerton Metals Company, a supplier of stock metal shapes in the Midwest, implemented an on-line bar code label printing system, which resulted in a payback period of six months due to a eighty five percent decrease in inventory manhours and a ninety percent decrease in lost material. Shipment of materials can be handled in much the same way. Material leaving the inventory can be entered into the data base by scanning the bar code and then entering in the purchase or project order number. The

receiver can enter the material received into his/her own inventory in the same manner.

The Department of Defense has long been a force behind the use of bar codes on consumer products. Since 1982, they have required all inventory items entering its supply system to contain bar code markings which would identify each item by its unique National Stock Number (NSN). As an example of bar code technology in the supplier area, consider the current system in use at Naval Supply Center (NSC), Norfolk, Virginia. Called the Naval Integrated Storage, Tracking and Retrieval System (NISTARS), the system controls the stowage and issue of 250,000 to 300,000 line items in the Navy's largest storage location. Up and running in October 1987 as part of an $82 million project, the system applies a unique NISTARS bar code to each item upon receipt, enters it into the data base, moves the item to its storage location by conveyor and finally, lifts the item by an automatic crane system to its storage bin. At issue, the process is reversed, except bar codes are added to the shipping container and used to generate the shipping documentation.

2.1.3 Construction Field Applications

Construction field applications can be divided into the following categories:

A) Field Material Receiving, Control and Inventory

B) Tool and Consumable Material Issue

C) Timekeeping and Cost Engineering

D) Purchasing and Accounting

E) Scheduling

F) Office Operations

G) Equipment Control

A) Field Material Receiving, Control and Inventory:

Construction materials can be broken down into the following groupings (Rasdorf-Herbert 90):

i) Uniquely identifiable materials and equipment such as steel beams, precast concrete items, door frames and transformers. These items are identified as unique because a bar code label can be directly attached to a single item.

ii) Bulk materials, like fill dirt, gravel, concrete and asphalt. These materials are identified as bulk since they cannot be directly labeled.

iii) Both bulk and unique materials, such that, although the material cannot be directly labeled, the container can be, like a spool of electrical wire.

Uniquely identifiable materials and equipment are individually marked by bar codes specific to the particular item. Figure 4 is an example of a structural steel beam bar

code label. Scanning the bar code attached to the material increases the speed and accuracy of the receipt process. The issue process works in the opposite manner. Inventory can be performed using a PDT, particularly if many on-site or remote storage areas exist. In addition, if engineered equipment items are shipped with permanent bar code labels attached, the basis for an owner capital asset inventory and maintenance tracking system is established during the construction process (Bell-Gillis 89). Bulk materials may be controlled using a menu tablet system, similar to that used in the quantity takeoff scenario. The menu tablet would contain bar codes created for each bulk material anticipated, along with quantity codes and action codes (receive, issue, inventory, install, etc.). Furthermore, a system of control could also be implemented given bar code use on material delivery tickets. If the ticket contained the type of material and quantity in bar code form, a PDT could be used to receipt the material as the delivery truck entered the job site. Obviously, the supplier would need to be involved in bar code technology for this portion to be successful. Combination materials (both bulk and unique) can be controlled using bar code labels attached to the item's shipping container. Receipt, issue and inventory would be easily accomplished on full lots but broken lots still would require manual or menu tablet entry for the less than 'factory issue' quantity.

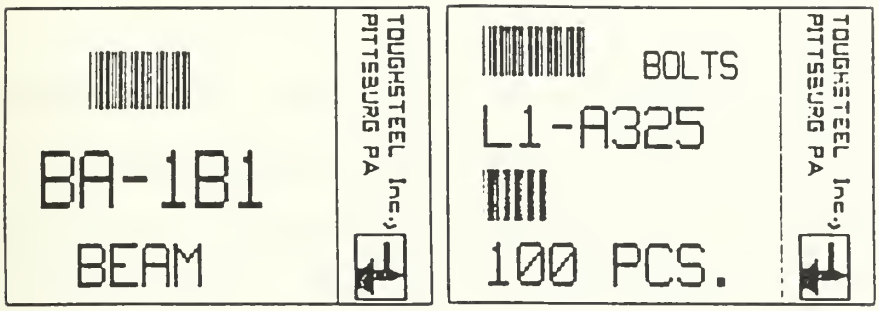


Figure 4

Structural Steel Beam

Bar Code Label

(Rasdorf/Herbert 90)

To make a bar code system work in this situation, however, would require the use of a consolidated project supply location. While project supply records are often kept by the General Contractor for invoice purposes, each trade contractor keeps their material in their own inventory, on-site or off. This method is counterproductive as it employs skilled labor to monitor the supply point vice a lower paid supply clerk. Additionally, this system often leads to a lack of accountability regarding lost or damaged material, promoting the use of higher contingencies in bid prices.

The benefits of bar coding in Field Material Control can best be illustrated by a pilot study conducted in 1987 (Bell-Gillis 89). The project selected for the study was a twelve month, forty million dollar facility expansion which included the purchase of some 3000 major material items. Approximately 2000 installed material items would be permanently bar coded to facilitate the initiation of a capital equipment inventory system. The system used vinyl labels attached to aluminum tags, printed on site by a laser jet printer. The majority of the labels were sent to the supplier for attachment prior to shipment, though field personnel were required to attach a minimal number. Because the owner implemented the bar code system at the same time he purchased an office computer system (which interfaced with the field material control system), cost savings associated could not be precisely determined. However, the

owner did observe significant improvements in labor productivity, while the system provided accurate and timely information for the purpose of trade labor planning.

B) Tool and Consumable Material Issue:

Bar code systems can be used to track the status of tools and the issue of consumable materials from the issue point. It may also be used to reduce lost and destroyed tools, flag required tool maintenance cycles, facilitate inventory and expedite reorder of materials and tools when in low supply. Implementation in the construction industry would require a central tool room manned by a full time monitor. This would replace the current method of allowing each contractor on the site to run their own tool control system. Consolidation would speed up the issue and inventory process and improve accuracy, while allowing a clerk to perform the monitor/issue function in lieu of skilled laborers collecting their own tools and consumables. Such a system in the industrial sector was described previously. Additionally, commercial computer software is readily available to implement a tool issue and tracking system directly into the project's management information system.

C) Timekeeping and Cost Engineering:

The use of time cards to collect hours worked, long the norm in all phases of industry, is a slow, complicated and error prone system. Bar code technology can improve this system with the use of a fixed bar code scanner and individually issued bar coded ID cards to each employee. In a manner similar to the time clock, employees would clock in and out of the job site by waving their ID cards across the fixed scanner. The fixed scanner would be connected directly to the job site computer system, where the creation of payrolls for invoice submission purposes could be simply and accurately produced. Further, additional information may be incorporated into the data base to identify the individual's trade and status. Using this information, daily reports on attendance could be generated quickly, giving management a tool to anticipate possible manpower needs before problems arise.

In addition to collecting the labor hours of a worker, the use of bar codes on pieces of equipment could help management track their usage and productivity, and whether the quantity of such equipment (by high or low use) is adequate for the job in progress.

D) Purchasing and Accounting:

The use of bar codes to facilitate the purchasing and accounting functions is merely an extension of the three areas already covered. Time card bar coding can quickly provide labor hours worked by a particular individual for payroll purposes. Purchasing can be executed by combining the bar code augmented quantity takeoff software with software that generates requisitions. Use of a bar coded system may also be tailored to " flag " requirements for the reorder of materials when the on-site inventory reaches a pre-designated low point. In this manner, work flow to the purchasing agent may be more even and, therefore, more accurately accomplished. Receipt of the material for the execution of payment to the supplier can be derived directly from the bar coded material control system. In all cases, provided the job site and home office computers systems are electronically linked, data can be transmitted as it occurs to allow daily cost accounting entries. If no electronic coupling exists, the floppy disk would replace the large volume of paper presented to the accounting department for manual entry.

E) Scheduling

The use of bar coding for scheduling combines the material control and issue process, the use of individually bar coded

employee ID tags and a computer software package. The material control and issue process announces the receipt and subsequent usage of job material. At the same time, incorporation of ID badge scanning can not only identify the number of employees at work on a particular activity but the skill level of each based on the person's paygrade. These two sources of information can help determine productivity and activities accomplished during the period under review. In turn, an updated project schedule can be accurately generated based on the past performance accumulated in the data base. Additionally, as more job site information becomes available, the schedule can be further refined to account for changes in productivity and may also help to pinpoint areas of concern.

F) Office Operations

In addition to the time keeping, purchasing and accounting uses of bar code technology previously discussed, the simplest application may be in the inventory of home office furniture and equipment. Periodic inventories can be accomplished quickly if all items over a certain value (in the Federal Government, all items with a value of over two hundred dollars require annual inventory.) are affixed with a bar code. Additionally, the bar code data base can be expanded to contain information on acquisition date and

maintenance performed to facilitate equipment replacement and budgeting.

Implementation of such a system was initiated in 1986 by a contractor task with the management of a very large United States Government facility. The manual control system, in place at the time of contract award, possessed the normal inventory characteristics : labor intensive, prone to error, slow, fragmented. An analysis of bar code applications versus manual applications revealed an estimated cost savings per year of $17,000, in addition to the improvements generally experienced with the implementation of a bar code system. Software development was undertaken, since the commercial versions were not as flexible as desired, and 11,000 items were inventoried and bar coded, an effort that required forty eight man-months of effort. The system described began operating in total in 1989 and has produce the expected monetary, accuracy and productivity improvements.

G) Equipment Control

Equipment recordkeeping, due to its manual entry nature, lends itself to automation by bar code technology. Application of a bar code strip to a piece of equipment whose data base is loaded with acquisition data and maintenance and inspection records would give management

timely reports on equipment status. As additional maintenance were to occur, updates to the data base would be accomplished. Location and use of equipment (not only hours, but how and when used) could be maintained using a PDT and menu tablet to collect information on the site. This type of information can prove to be beneficial when determining the frequency of equipment use or its maintenance and service requirements (Rasdorf-Herbert 90). Additionally, equipment usage trends may identify opportunities to reduce costs by using the rental option.

The key to the use of any bar code application in construction relates to the speed in which information can be relayed to management. Real time analysis of equipment, personnel and material status' as well as productivity can aid the decision maker in the execution of field adjustments crucial to keeping the project on time and within budget.

2.2 BAR CODE MATERIAL SELECTION AND TESTING

The United States Army Logistics Symbology (ALOGS) Division, the United States leader in the development of bar coding technology and its implementation, has conducted extensive analysis of bar coding materials and their implementation in a variety of different working environments. Two documents, MIL-STD-130G Information, Bar Code Marking Information for End Item Material and MIL-L-61002, Labels, Pressure Sensitive Adhesive for Bar Codes and Other Markings, both released in 1990, outline the Department of Defense requirements for placement and construction of bar code labels. Though neither publication or any of the sixteen test reports on bar code materials specifically considers construction industry uses, material tests implemented can be utilized to select a proper bar code material given any of the following construction uses:

A) Construction Equipment Marking

B) Construction Material Marking

C) Design Drawing Marking

D) Office Equipment Marking

E) Tool Identification and Tracking

When selecting a material for bar code markings, the following factors require careful consideration in relation to the environment in which the bar coded end item will be used:

A) Temperature, especially if the bar code will be applied on site.

B) Desired serviceable life span of the bar code label.

C) Properties of the material to which the bar code label will be attached.

D) Specific conditions (ie; scratching) which the bar code label will be required to endure.

Temperature considerations are perhaps the most important of the four. The label must be constructed to prevent or minimize smearing, delaminating, loss of adhesion, discoloration or wrinkling under a range of temperatures from well below zero degrees Fahrenheit to in excess of one hundred degrees Fahrenheit. If the label is to be applied in the field, the air temperature at application will dictate the level of label material, adhesive material and installation equipment sophistication. Also, the requirement to be serviceable for an extended period of time will dictate different types of label materials. Lastly, in the construction arena, many bar coded items could be thrust into an environment in which they could sustain damage due to the elements (ultraviolet radiation or salty air) or physical handling (scratching, marring, solvents or detergents), thus losing their reflectivity.
Implementation of a bar code system will require careful evaluation of these issues to correctly choose the bar code label materials best for a particular phase of the operation.

Label Mtl	Svc Temp Range 1/	Abrasion	UV Resistance	Moisture	Salt	Svc Life 2/
Paper, Thermal	-50 to 140	F	P	P	P	<1 yr
Paper w/o Laminate	-50 to 140	P	F	P	P	<1 yr.
Paper with Laminate	-50 to 140	G	F	F	F	1-3 yr
Plastic w/o Laminate	-50 to 200	P	G	G	G	1-3 yr.
Plastic w/ Laminate	-50 to 200	VG	G	VG	VG	1-3 yr.
Polyimide	-50 to 600+ short dur.	P w/o Lam	G	G	G	1-5 yr
PVF	-50 to 200	P w/o Lam	E	VG	G	1-5 yr
Photo-Sens Alum	-50 to >1000 3/	E	E	E	E	>5 yr
Metal	-50 to >1000 3/	G	E	E	G	>5 yr.
Ceramic	-50 to >1000 3/	G	F	E	E	>5 yr

P=Poor. F=Fair. G=Good. VG=Very Good. E=Excellent

1/ Labels suitable for application temperatures lower than forty degrees Fahrenheit shall be specified

2/ Service life of paper and plastic labels may be improved by use of protection overlaminate. Service life shown is for harsh environment.

3/ Fasteners such as screws and rivets may also be used

Table 1

Relative Label Environmental Suitability

(MIL-L-61002)

The use of a bar code material testing results, conducted by ALOGS and produced in a tabular format, make it easy to make an initial selection of bar code material type. Table 1, Relative Label Environmental Suitability, provides a matrix that shows relative strengths and weaknesses of particular bar code materials under given conditions. An extension of Table 1, Table 2, titled Bar Code Label Considerations, further breaks down each material category into different levels of performance. The basic and most cost effective label type is annotated by an "A". Cost of the label and level of performance increases in descending order of the materials listed. Additionally, bar code labels can be produced by different processes, as shown in Table 3. One notable comment made in this table is the applicability of in-house printers to produce labels and the ability to affix different types of labels in the field, certainly a plus towards implementation in the construction industry.

Item	Label Construction		Additional Considerations
	Substrate	Laminate	
	PAPER		
1A	70# Paper	P-propylene	Least expensive durable label
			Cardboard, smooth surfaces
1B	70# Paper	P-propylene	For frozen environments
1C	70# Paper	P-propylene	Removable adhesive
1D	T Transfer	P-propylene	Thermal transfer printing
	THERMAL PAPER		
2A	Thermal	N/A	Buff colored label.
			For indoor use only
2B	Thermal	N/A	For low temp/frozen environments
2C	Thermal	N/A	For "no stick" surfaces.
2D	Thermal	N/A	Removable adhesive
			Can be repositioned.
	VINYL		
3A	Vinyl	P-propylene	Most economic choice for
			intermittent outdoor exposure
3B	Vinyl	P-propylene	For "no stick" and textured
			surfaces (office equip, etc)
3C	Vinyl	P-propylene	Removable adhesive.
			Can be repositioned.
3D	Vinyl	P-propylene	Good for most untreated metal
			surfaces.
3E	Destruct.	P-propylene	For destructible asset
			management labels.
3F	PVF	PVF	UV resistant label for extended
			outdoor use.
3G	PVF	PVF	UV resistant label for outdoor
			use, esp. untreated metal.
	SPECIAL PLASTICS		
4A	P-propylene	P-propylene	Sub. for 3A. Better tear resist.
4B	P-propylene	P-propylene	Acid resistant Especially good
			for "no stick" surfaces.
4C	Acrylic	PVF	UV resistant label for
			extended outdoor use.
4D	------	RED	Red overlaminating film for
			"photocopy proof" labels
4E	------	BLACK	Black overlaminating film for
			non-human readable labels.

Table 2

Bar Code Label Considerations

(MIL-L-61002)

Item	Label Construction		Additional Considerations
	Substrate	Laminate	
	POLYESTER		
5A	Polyester	Polyester	Best all around durable label
5B	Polyester	Piggyback	Used for painting/staining operations
5C	Metallized	Polyester	Metal tag appearance - asset management; tamper evident
5D	Mtl "VOID"	Polyester	Metal tag appearance - asset management, tamper evident
5E	White "VOID"	Polyester	Asset management, tamper evident
5F	Polyester	Polyester	For automatic application - Same properties as 5A
5G	Polyester	Polyester	Autoclave resistant Excellent for glass surfaces
5H	Polyester	Polyester	For untreated metal surfaces
5I	Polyester	PVF	UV resistant label for extended outdoor use
5J	High Temp PE	Polyester	Non-solder side of PCBs during mftg process.
5K	High Temp PE	Polyester	Non-solder side of PCBs; laminate on backing paper
5L	High Temp PE	Polyimide	Low cost alternative for solder side of PCBs.
	POLYIMIDE		
6A	Polyimide	Polyimide	General use for solder side use in PCB manufacture
6B	Polyimide	Polyimide	Higher temps than 6A.
6C	Polyimide	Polyimide	Highest temp performance for solder side of PCBs.

Table 2

Bar Code Label Considerations

(Continued)

Marking Technology	Description	Uses	Employment
Laser Etch	Marking process which employs a microprocessor controlled laser to destroy the surface molecular structure. Etched material must produce a bar code with the required PCS.	For plastics, metals or ceramics where highly durable bar code markings are required and where no contaminants are present.	Appropriate for application at manufacturing, depot, and support maintenance facilities.
Direct Print	Conventional print process involving the deposit of ink under pressure to imprint an image. Includes such print technologies as flexography, offset lithography letterpress, letterset, silkscreen and rotogravure.	To produce large quantities of high quality, identical markings or labels. May be integrated with rotary printer or another print technology to sequence or otherwise vary bar coded information. May also be employed to mark items or containers directly.	Appropriate for productiion at printing plants. Pressure sensitive tags or labels can be applied on site.
Dot Matrix Impact	Computer controlled printhead produces a series of dots in a pattern so that it forms a character. A series of solenoid driven needles strike an inked ribbon, ink is tranferred to the label stock.	Flexible, low cost production of bar coded labels, tags, or forms. Shuttle bar printer is used for line printing and serial, or moving head printer, for character printing.	Most common kind of in-house printer but also appropriate for use in a plant setting. Least desired technology for marking bar codes.
Formed Character Impact	Characters to be printed are etched on a drum over which label stock and carbon ribbon are fed. The hammer strikes when the designated character comes around on the rotating drum, forming one complete bar code character.	Production of bar coded label or tags.	Suitable for on site printing and application.

Table 3

Bar Code Marking Technologies

(MIL-L-61002)

Marking Technology	Description	Uses	Employment
Ion Deposition	Ions projected from a computer-controlled print cartridge form a latent image on a dielectric cylinder which is developed by adhesion of toner to the charged areas. The toner is simultaniously transferred and fixed to the printed surface under high pressure.	Production of labels and tags. Often integrated w/direct printing in a continuous web operation to add variable info such as sequentially numbered bar codes to labels printed by another process.	Appropriate for printing or computer facility but labels or tags can be applied on site.
Laser Toner	Computer controlled laser beam forms image by neutralizing charges on a charged photo-sensitive drum. A carbon toner is applied and adheres to the charges areas, developing the image which is transferred to the substrate and fixed by heat and pressure.	To produce bar coded labels, tags, and forms on cut sheet media where heat and pressure will not adversely affect label adhesives.	High speed printers are normally used in a printing or computer facility. Low speed printers are suitable for light duty use on site. Easily applied on site.
Photo Composition	Image is projected onto a photo-sensitive substrate. The substrate is then processed in the same manner as a photograph to fix the image.	To produce archival quality, bar coded labels and tags on paper, plastic, and metal substrates.	Most appropriate for offsite production by an outside vendor but can be applied on site.
Thermal Direct	Microprocessor-controlled printhead contains an array of tiny, resistive dots which provide heat necessary to cause a chemical reaction in a specially treated paper as it moves past the printhead, turning the exposed areas black.	Low cost, flexible format labels and tags. Widely used in retail sales and food industry to mark items and shelves. Indoor use only.	Simple, reliable technology appropriate for on-site printing and application. Can be used with paper labels only.

Table 3

Bar Code Marking Technologies

(Continued)

Marking Technology	Description	Uses	Employment
Thermal Transfer	Similar to thermal direct but uses a thermally sensitive printing ribbon. Stylis are heated selectively, melting waxy ink onto the medium to form an image.	Combines flexibility of thermal printing with quality and durability of impact printing.	Appropriate for on-site printing. Comparable in terms of simplicity and reliability with thermal direct printing.

Table 3

Bar Code Marking Technologies

(Continued)

2.3 SUCCESSFUL USES OF BAR CODE TECHNOLOGY

Despite years of successful use in other industries, bar code technology is merely in its infancy stage when one looks at construction industry utilization. However, a few construction/facility organizations have successfully implemented bar code systems within their existing operation and what follows is a brief synopsis of how they did it.

A) The George Hyman Construction Company (GHCC), a large general construction company with offices all over the continental United States, maintains a workload of 20 to 40 active projects at any given time. In support of this effort, the firm owns and operates over 3000 individual pieces of construction equipment and tools, which are dispatched to each job from a central yard. To control the flow of these assets and non-consumable job materials to the project site, GHCC originally developed a manual construction yard management system. This system required the manual entry of information such as the transfer date and quantity of equipment or material into a PC for use in tracking project costs. The manual system, shown in Figure 5 , contained nine steps as follows :

STEP 1, ORDERING - An order by the jobsite superintendent to the central yard for required equipment/materials.

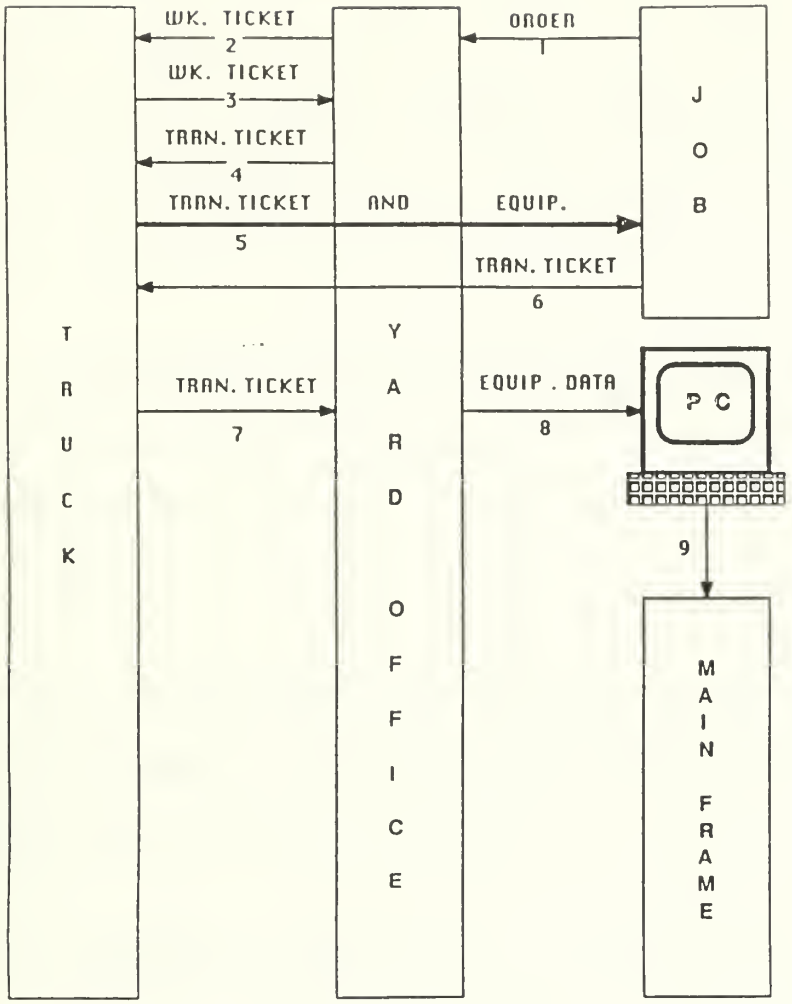


FIGURE 5

GHCC MANUAL SYSTEM

(Bernold, 1990)

STEP 2, PREPARATION OF SHIPMENT - Work tickets are created which define the equipment/material to be delivered to a certain destination. The truck driver confirms the order, notes the specific identification number on each item to be delivered and loads the truck.

STEPS 3 & 4, PREPARATION OF TRANSFER TICKET - With all equipment/material loaded, two copies of a formal transfer ticket (required for each item movement) are provided to the truck driver.

STEPS 5, 6 & 7, SITE DELIVERY - Upon arrival at the site, one copy of the transfer ticket is signed by the jobsite superintendent acknowledging delivery.

STEPS 8 & 9, INFORMATION PROCESSING - All transfer tickets are collected at the central yard office. Costs are applied at a standard usage rate for each type of equipment transferred and this information is entered into the central yard office's PC. After checking for errors, the information is uploaded into the main office's mainframe computer.

In an attempt to streamline the existing system, GHCC turned to bar code technology. Since GHCC decided early in the implementation process to prevent disruption of the existing

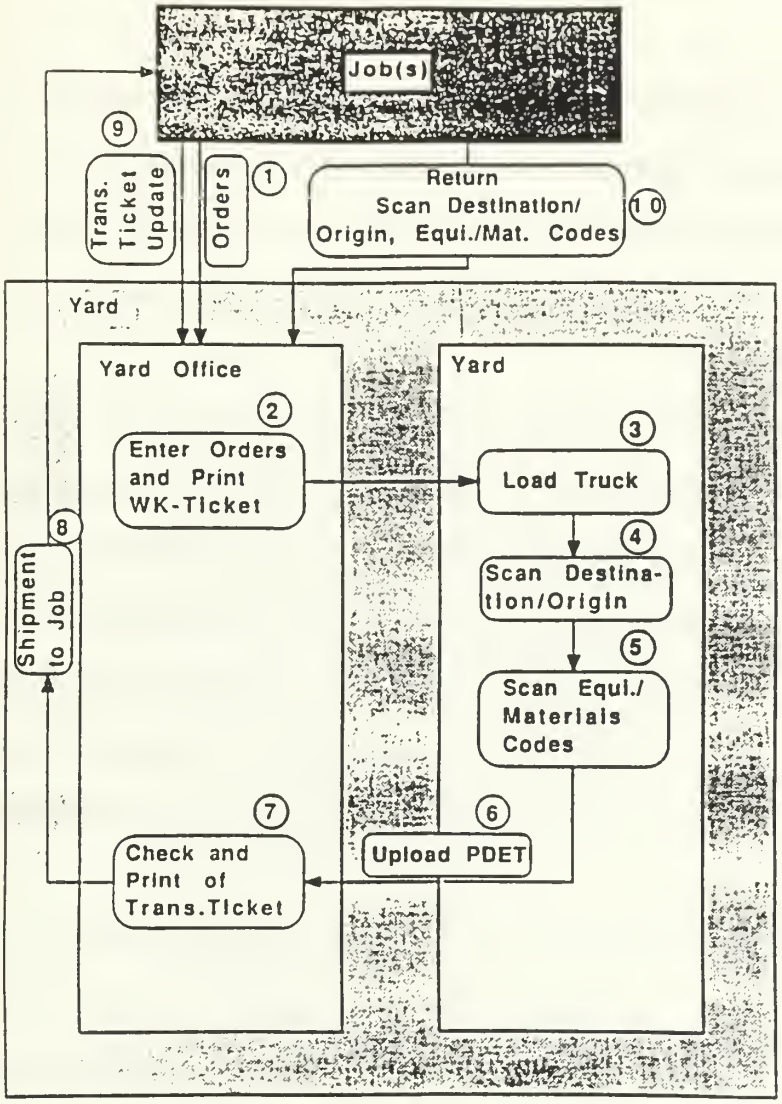


FIGURE 6

GHCC BAR CODE SYSTEM

(Bernold, 1990)

workflow, a modified delivery sequence model was developed as shown in Figure 6. This model contained the following ten steps.

STEPS 1 & 2, ORDERING - Accomplished as previously, except the jobsite superintendent enters the equipment/material request into the jobsite PC, connected to the central yard office PC by modem.

STEPS 3, 4 & 5, RETRIEVAL OF ORDERED ITEMS - Work tickets are still used to identify the items to be transferred. However, input of individual equipment/material identification numbers are entered into the central yard office PC by reading the bar code attached to each item with a PDT. This process is accomplished as the equipment/material is loaded onto the truck.

STEPS 6 & 7, ORDER VERIFICATION - The central yard office PC verifies the order by comparing the uploaded equipment/material identification number data with the original jobsite order. The equipment/material condition (loaded versus not loaded) is also verified at this time.

STEPS 8 & 9, DELIVERY - After delivery of the equipment/material to the jobsite, the truck driver returns the transfer ticket containing the delivery acknowledgement

to the central yard office, where the actual date and time of delivery is added to the PC.

STEP 10, RETURNS - Return of the equipment/material to the central yard is accomplished using a transfer ticket and a PDT to record each individual asset separately.

The use of bar codes, in this instance, enabled management, at all levels, to assess equipment/material utilization on a real time basis. In eliminating much of the manual effort, the central yard control system, utilizing bar code technology, improved productivity by reducing administrative time in the office as well as the ability of the staff to catch errors and correct them prior to dispatch. Furthermore, the system provided an accurate accounting of work hours by equipment type, facilitating the development of actual hourly costs (vice using a standard rate) and the scheduling of routine maintenance and equipment replacement (as well as its effect on future project costs and bids).

B) Fluor - Daniel (FD) Incorporated, one of the largest construction contractors in the world, implemented a bar code system designed to track the cost and location of tools and supplies on its $20 million Virginia Power nuclear plant project. The company had previous experience using bar code applications, primarily in its Houston, Texas operations

center (for example, material take-offs). Because this was the first time FD had attempted to implement such a system, the in-place manual system was left in service, with the bar code system primarily to serve as a back-up. During the initial development of the data base, site personnel were required to obtain stock and bar code numbers for each tool, bin locations, minimum and maximum inventory levels, existing inventory and prices, employee identification numbers (from their bar coded badges) and inventory already checked out through the manual system. Tools were checked in and out by scanning the tool's bar code and employee identification card bar code. Only tools checked out for more than one day's use were recorded in this manner. Others were shown as ' gangbox ' checkouts and were entered manually into the PC.

To increase inventory accuracy, a cycle count module was added to the system. Each bin location was assigned a cycle count code, which was changed each work day. Each day, an attendant scanned each bin for the cycle count code and entered the units present in the bin into the PC. This information, when compared to the records of what was supposed to be in the bin at that given time, allowed for discrepancies to be reconciled on a daily basis. Additionally, the gathering of tool count information allowed management to accurately assess and initiate the reorder of assets. Two major problems existed with FD's

efforts to implement this bar code system. First, labeling of tools only occurred when the value of the item was over $50 and then, problems persisted regarding the length of time the bar code label would stay affixed to the tool. In addition, many of the labels which remained affixed suffered from sufficient damage to cause them unreadable. Second, the proper training of all craftsmen on the job was impeded by project progress, since the bar code system was implemented after the project had started. In conclusion, FD was satisfied that such a system can work on a construction site. While not able to quantify monetary savings accrued as of yet, " The initial installation provided us with proof that such a system can work on a construction site if it is given the proper attention and priority ", according to Mr. Stan MacIntyre, an Industrial Engineer with FD. Despite the success of this rather narrow scoped project, FD has yet to fully implement bar code technology in all of its projects. Further demonstration projects are necessary, in my opinion, but with a scope much larger (ie; cover more functional areas) and the reliance on a back-up system removed to ensure realistic results for evaluation.

C) The proper maintenance of construction equipment can be one of the most important facets in the successful completion of a project. While no information regarding contractor use of an equipment management system utilizing

bar coding has been discovered, in 1988 the United States Army implemented a system designed to improve the management of the assets assigned to the Directorate of Engineering and Housing (DEH) at Fort Lee, Virginia. Under the original process, two supervisors spent most of their time ordering parts, maintenance records were kept on paper in several file cabinets and a preventive maintenance backlog existed, which resulted in the under utilization of the mechanics. JP Systems, Incorporated, of Greensboro, NC, was awarded a contract to install a system called SHOPFAX, on a turnkey basis. The original configuration of one main computer, three workstations, two bar code wedges, two bar code wands, seven bar code readers and two dot matrix printers plus the software and training required was acquired for approximately $50,000 (1989 dollars). The installation of the system required only three days, while the training of largely computer/keyboard illiterate mechanics took one week. At Fort Lee, the bar code system has been credited with improved record keeping (2.5 man-years saved in the first year), improved mechanic efficiency (better maintenance efficiency resulted in less brakedown maintenance in the field), an elimination of the preventive maintenance backlog, incorporation of a decision making mechanism concerning equipment lease versus purchase, warranty monitoring and an improvement in parts inventory based on anticipated demand (by scheduled preventive maintenance), heavy usage or long lead time to acquire.

Simply stated, the savings on improvements generated in the Fort Lee DEH equipment shop far outweighed the annual cost of $6900 for system maintenance and software upgrades.

The project enabled the U.S. Army to prove to itself that implementation of bar code technology can improve an operation's efficiency. The scope of the project was developed to fully test whether bar coding could entirely support their equipment operation. The answer was a resounding yes. Based on the results obtained, the U.S. Army has begun to execute plans to install bar code technology in all of their equipment shops.

CHAPTER 3

IMPLEMENTATION PLAN FOR BAR CODE USE IN CONSTRUCTION

3.1 INTRODUCTION

In the preceding pages, many potential, and in some cases, implemented uses of bar code technology in the construction industry were described. A few organizations have taken the plunge into the bar coding world, but have limited themselves to a narrow scope, one that would not interfere with the current operation in place. This indicates not only a reluctance to try something new but also a continuation of the failed unwritten policy in the construction industry of ignoring advances in technology if doing so effects overall profits. Failure to remedy this shortcoming will hasten the decline in the competitiveness of the American construction industry. Implementation of bar code systems is a logical first step in overcoming this barrier. It is not a new technology, for many industries in this country already employ it in some degree. The goal of this chapter is to propose an implementation plan for initiation of an integrated bar code system that can be used to monitor specific phases of a construction project from both the owner's and contractor's point of view. Specifically, this plan will address those items with which the Assistant Resident Officer In Charge of Construction

(AROICC), under the direction of the Commander, Naval Facilities Engineering Command is most interested in the proper performance of the duties assigned. To this end, the following areas will be explored and implementation specifics generated :

A) Labor Hours

B) Construction Equipment Costs and Utilization

C) Material Control

D) Document Control

3.2 LABOR HOURS

The implementation of bar code technology in the labor hours (time card) area should be the first attempted since it is the least time consuming and lowest cost among possible applications. The goal is to simplify the administrative process associated with the submission of employee payrolls, required by NAVFAC when requesting a progress payment. By replacing the standard time card with time clock punch (or, the filling out of the time card or sheet by hand), the construction firm will improve the accuracy of the payroll by eliminating the manual or mechanical entry to the time card, which is prone to error if the time clock malfunctions or if the entry is unreadable. The confidentiality of hours worked by a particular employee will improve, long a labor problem due to the competitive nature of obtaining overtime work. The speed involved in the check-in and check-out process will be substantially increased, eliminating much of the time necessary for employees to stand in line to clock in and out from breaks and at the end of the shift. Lastly, since a bar code system provides real time data, supervisors can easily and quickly identify absentees at the beginning of the work day, allowing management to obtain skilled labor from other sources to fill the void or shift the work schedule to allow for the lack of necessary employees.

To make a system such as this work, the bar code time clock should be located in a covered central location, preferably

adjacent to the superintendent's office. A specific number of clocking evolutions should be pre-determined for input into the computer. This number should, however, be kept as low as possible to limit unnecessary labor movements to the clock location as well as to minimize the amount of administrative time associated with the review of each time card input. For example, if each employee was to clock-in at the beginning of the work day, clock-out for lunch, clock-in from lunch and clock-out at the end of the work day, the computer would recognize each activity by the order in which the number of time entries was made. Holidays, vacations, sick days and other non-working days which are known in advance of their occurrence, in addition to pay scales and overtime policy, would be entered into the particular employee's time record via a computer workstation. To separate and identify the workers for different companies on the site, an unique block of identification numbers could be assigned to facilitate sorting by firm. In addition, consolidation of the time keeping process would eliminate the need for the prime contractor to obtain the payrolls from each subcontractor prior to submission of the progress payment request. Furthermore, the accuracy and the timeliness of the payroll recording system would lead to accelerated identification of labor budgeting and scheduling problems.

One may argue that a natural extension of the labor hours phase would be to track what each employee does and for how long. While a contractor may be interested in such a system, this system would attract limited Federal Government interest since fixed price lump sum construction contracts are primarily used and the burden of tracking worker productivity is placed on the contractor. Initiation of a labor hours tracking system would provide the contractor with valuable information with which to substantiate claims and refine bids due to real time and accurate labor productivity reporting. However, the difficulty would lie in defining a work item listing detailed enough to provide meaningful data but not overly detailed so as to require constant updates in the data when small changes in the work tasking are accomplished (ie, install toilet and install sink vice install plumbing fixtures). There is no doubt that the Federal Government would benefit from such a system through theoretically lower, more accurate bids (and hence, lower contingencies). However, while the Federal Government should encourage its contractors to experiment with the implementation of advanced technologies, such an initiative should not be underwritten since this type of information is of little use (if any) to the AROICC in the performance of assigned responsibilities.

The benefits of installing a labor hours system utilizing bar code technology is threefold :

1) The administrative time required to process payrolls accurately would be decreased. Errors in the labor data could be corrected daily, if necessary, and changes in labor rates or overtime policy could be inserted in the data base with little effort.

2) The administrative time necessary for the Federal Government to review the payrolls would be reduced to checking for compliance with federal labor laws. All other factors, such as checking for math errors, would be eliminated due to the accuracy of the system in operation.

3) Overall contractor management of the workforce would improve. Not only would the superintendent be able to quickly adjust the work schedule or workforce based on the real time labor data available, but the contractor would also have an automated record of actual work hours utilized to perform pre-defined job tasks, easily assessable for bid preparation and more accurate than estimating guides or " experienced " based guesses. The overall result should be more realistic project cost estimates and the submission of lower bids to the Federal Government for construction projects.

The set-up of a labor hours system utilizing bar code technology would require the following :

1) The issue of a unique bar coded identification card to each job site employee. The card should be laminated to protect it from the elements and other job site hazards which could cause the bar code unreadable.

2) A stand alone bar code decoder with slot scanner (see Figure 7) for entry of employee movements. The unit may be remote (ie, send the data via an antenna to the receiving unit or collect the information for future download), or connected directly to a PC. In addition, consideration must be given to location of the unit with regards to its ability to withstand the environment.

3) Computer software compatible with the existing PC structure, if available. The software may be pre-packaged or written specifically to the user's criteria. Communication software may also be necessary, if transmission of data between the field office, home office and OICC, in lieu of using paper and the mail, is desirable.

4) PC with modem (internal or external) at the field office (for data insertion), the home office (for

data compilation and review), and the OICC, as a minimum. If electronic transmission is not feasible, the modem may be omitted and data may be submitted through each step using floppy disks, with a resultant slowdown in the process to follow.

The specific strategy for acquiring the necessary technical expertise and products will be discussed at the conclusion of the Document Control section.



Figure 7

Typical Slot Scanner

(Palmer 91)

2.3 CONSTRUCTION EQUIPMENT COSTS AND UTILIZATION

The implementation of bar code technology in the construction equipment area is a bit more complicated than the labor hours area. First, the process involves an inventory phase which most construction firms accomplish on some predetermined time schedule. Second, the usage phase tracks the primary task of each equipment item and the operation and maintenance costs associated with the task to formulate hourly usage rates. Third, a smooth running construction company requires smooth running equipment, so a maintenance phase is developed with an eye toward the relationship between hours used and maintenance required for each individual equipment item.

In the inventory phase, a comparison is drawn between the Federal Government and the private construction company. Within the Federal Government, each piece of equipment is registered on a property record card when received, with the property record card serving as the basis for recording the results of the annual inventory. The property record card contains some identifying information, like a serial number, and typically the person or department which is in possession of the item. When the inventory is performed, a person, carrying the property record card, must physically locate the item and verify its identity by comparing the serial number on the card to the one posted on the

equipment. Assuming the private construction contractor performs the annual inventory in generally the same manner, the use of bar code technology can streamline this process in three ways :

1) Use of a bar code eliminates the need for a paper record. The inventory person merely scans the bar code for later comparison with the inventory data base. Additionally, time would be saved when compared to making manual entries on the property record card.

2) Use of a bar code improves accuracy by eliminating the search by the inventory person for identifying features present on the equipment for comparison to the property record card. Since the equipment will be solely identified by its bar code, no transcription errors or lost property record cards are likely to inhibit the performance of the inventory.

3) Within each computer based property record, a detailed location for each piece of equipment is annotated. Thus, time will be saved by eliminating the search for the equipment in question.

While the OICC has no desire to become involved in a contractor's annual inventory process, a streamlined system should reduce total overhead costs incrementally. The

result should be a small decrease in the overhead rates charged to the Federal Government.

The usage phase is designed to assist the construction contractor better track the costs associated with performing particular tasks with individual pieces of equipment. The bar code attached to each piece of equipment can be used to identify tasks and hours worked per equipment item. The contractor can use this information to analyze production rates and costs, which may signal problem areas dictating a need for further investigation. Indirectly, the contractor can determine which equipments are underutilized for possible redeployment to other job sites. Additionally, by keeping close track of hours used, the contractor is able to better forecast future equipment acquisition requirements, be it by purchase or rental, and perform the necessary budgeting for these often big ticket, long lead time items.

The maintenance phase is closely related to the usage phase. By tracking hours utilized, the maintenance staff can better forecast preventive maintenance requirements, and in doing so, can alert the superintendent to make alternative equipment arrangements due to particular assets going out of service for maintenance. By tracking repair and maintenance costs, the construction contractor, with the application of the usage phase data, can determine accurate, historical hourly equipment rates for use in change order negotiations

and future bid formulations. Furthermore, the maintenance phase will also provide information to the decision-maker regarding the lifespan of current equipment and the need to secure a replacement.

It is in these two areas that the OICC would have the greatest interest. With a data base such as described above in place, the construction contractor could utilize more accurate hourly equipment usage rates within the bid formulation structure, resulting in a reduction of the contingency used by the elimination of " estimated " hourly rates in favor of rates based entirely on actual historical costs. Theoretically, this action should result in lower fixed price bids for Federal Government construction work. Furthermore, up-front provision of these historically based equipment rates to the OICC would remove the requirement to negotiate this item in change order situations. Additionally, since the amount of equipment capital is a required input for calculation of profit under the weighted guidelines method, an automated system which maintained a listing of equipment purchase prices and acquisition dates would help to simplify and speed up the process of profit percentage determination in negotiated actions.

To initiate installation of a bar code system, each piece of equipment must be assigned an unique identification code or number. Within each identification code or number file, the

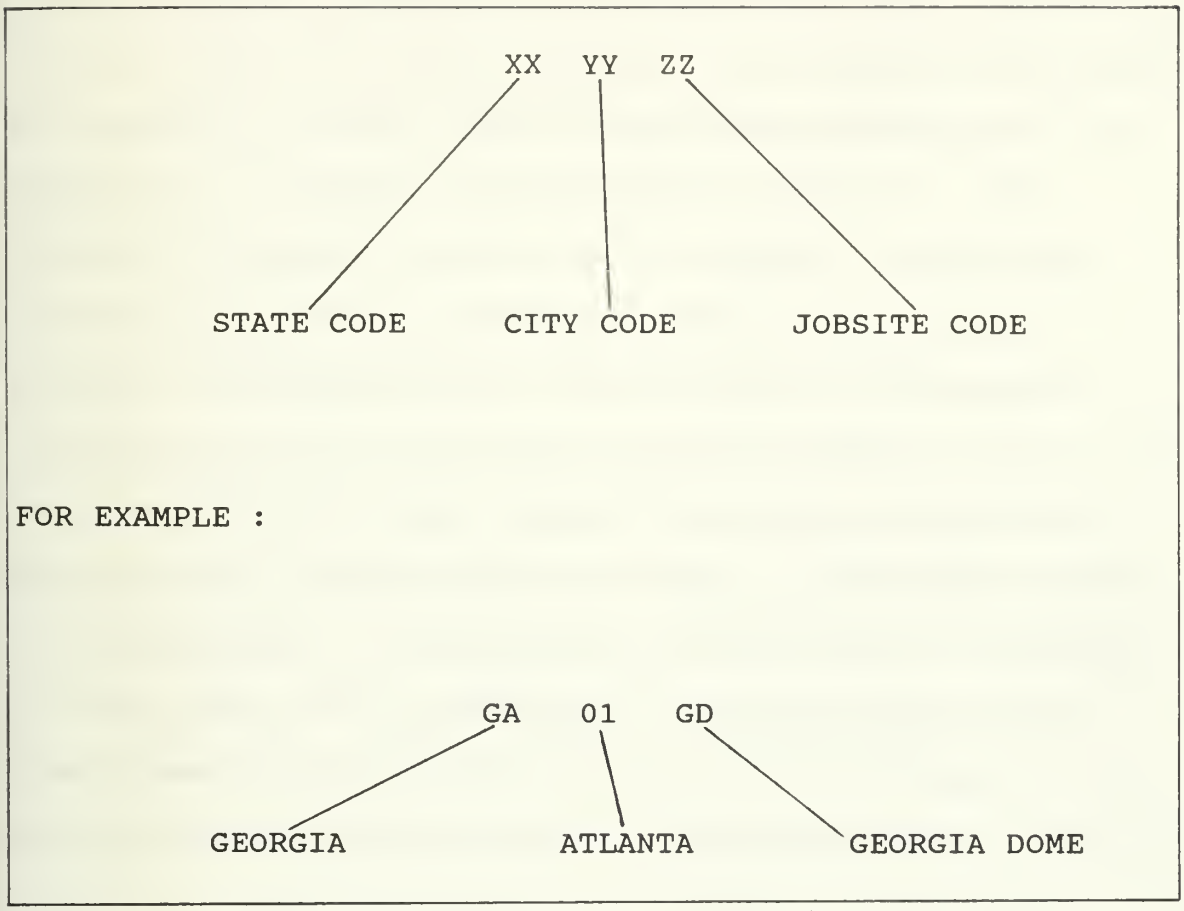


Figure 8

TYPICAL LOCATION CODE

acquisition price and date, serial number, description, location code or number and any other data which may help to identify the item should be added. The location code should be designed to simply identify where the equipment is. An example of a location code is shown in Figure 8. For inventory purpose, the code can be changed to denote new locations as often as necessary. Next, a listing of standard job identification codes requires development, irrespective of the equipment item performing the work. The job identification codes should be as simple as possible, but must also clearly define the type of jobs necessary for billing purposes. If the job definitions are too detailed, too much data will be produced or employees will become discouraged with the system and discontinue its use. Lastly, creation of a maintenance file per equipment item is required. This file should not only contain a record of past repair and maintenance activities, but also a detailed listing of each preventive maintenance action required and at what interval. The preventive maintenance listing can be further utilized to create a printed work order for the maintenance division.

The benefits of installing a bar code construction equipment system are as follows :

1) Annual inventory costs will decrease through the elimination of paper records and the use of location

codes in the bar code data file (which will reduce the number of personnel and time required to perform the inventory). A portion of the associated costs savings should be passed to the Federal Government through lower home office overhead rates.

2) Annual inventory results will be more accurate through the elimination of paper records (which can be misplaced) and the use of manual entries, which can lead to mistakes in record making and interpretation. This accomplishment should also be reflected in lower home office overhead rates.

3) Hourly equipment usage rates will be more accurate and more timely, given the improved method utilized in capturing the necessary data. With the accuracy of the " new " rates, contingencies concerned with the equipment area can be reduced, resulting in lower bids submitted to the Federal Government (through lower direct costs) and theoretically, a larger volume of business for the contractor, given his " sharper pencil ".

4) Improved management of equipment through the use of a computer based maintenance system which identifies maintenance requirements by equipment type and rate of usage. Better management in this area will lead to

improved equipment availability and more timely replacement of equipment whose hourly cost is unprofitable to the contractor due to wear and tear. In most cases, better maintained and newer equipment will cost the Federal Government less through lower hourly equipment usage rates (better fuel consumption and lower maintenance requirements due to minimal wear and tear).

The set-up of a construction equipment system utilizing bar code technology would require the following action items :

1) Selection of a suitable bar code material - This step may be the most critical, in that failure to select the appropriate material will destroy the effectiveness of the program. Referring to Tables 1 through 3 shown earlier in this report, the recommended label material for construction use would be Polyvinyl Fluoride (PVF), sealed with a PVF laminate. This material has a service temperature of -5 to 200 degrees Fahrenheit, rates a grade of good in abrasion resistance, excellent in ultraviolet resistance and a very good in moisture resistance. Furthermore, the lifespan of the material ranges for one to five years under extreme conditions. In addition, consideration must be given to the adhesive type to be used with the PVF material. The adhesive selected should be a

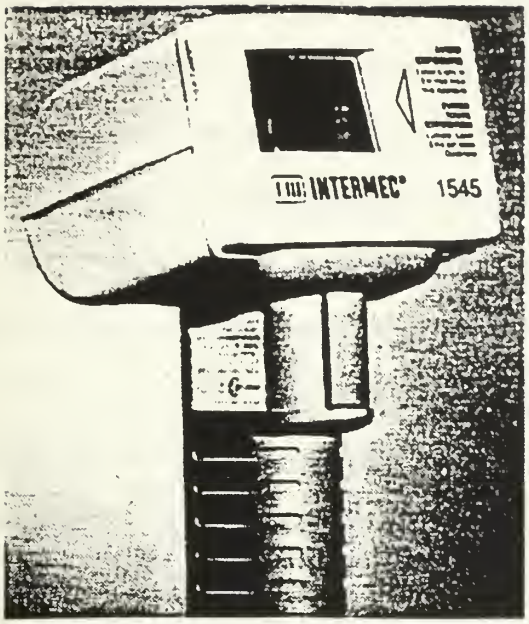
pressure sensitive type (so it can be installed in the field), with a thickness prescribed for exterior use of not less than five mils.

2) Selection of a bar code marking method - Again, reference is made to Tables 1 through 3. The recommended method should involve the direct point marking technology, since it is one of only a few technologies compatible with the material selected. This method will produce a quality label that will last a number of years without requiring replacement. The labels, however, may require off-site manufacture, but doing so would eliminate the need to acquire a bar code printer and the follow-on operator training.

3) Determination of bar code location - Despite the bar code materials apparent resistance to the environment, the lifespan of the bar code will greatly increase if positioned out of direct contact with the weather. With this in mind, the bar code location should be inside the operator's cab, or if no cab exists, within the operator's area (for example, on the seat frame or on the dashboard). Every effort should be made to standardize the location, if possible, to facilitate each phase of the program (for example, in the upper right forward corner of each operator cab).

4) Selection of a PDT - PDTs, with belt holder, will be necessary for each foreman responsible for the daily activities of construction equipment, the maintenance shop and at least one for the division responsible for performing the annual inventory (see Figure 9). Each foreman would be responsible for scanning the bar code for each equipment at the beginning of the shift and then entering a job type using a menu board with bar codes assigned to each job. The menu board would be constructed similar to the one displayed in Figure 3. If a job was completed before the shift's end and another assigned, the foreman, using the menu board would log out the first job with the number of hours worked and log in the new job. At the end of the shift, the foreman would close out each piece of equipment in the same manner and download the data into the field office PC for further review and dissemination.

The selection of a PDT is also an important issue. In addition to physical durability, the PDT should read the bar code using a technology known as moving beam scanning. This method of scanning attempts a bar code read many times each second, giving them an advantage when reading old, dirty, scratched symbols (Sharp 90), indicative of what conditions are typically present on a construction site.



Courtesy of Intermec Corp.



Courtesy of Symbol Technologies, Inc.

Figure 9

Typical PDTs

(Palmer 91)

5) Selection of a computer software, compatible with the existing PC structure, if available - Though pre-packaged softwares are available, they are geared only toward manufacturing (vice equipment usage), inventory or equipment maintenance (SHOPFAX) separately. The preferred solution would create a user specific, integrated software package which would control the Construction Equipment area within one program. The comments regarding communication software, made in the Labor Hours section, remain valid.

6) Acquisition of PCs - The PC requirements remain the same as that detailed in the Labor Hours section, except that an additional unit is now required in the maintenance shop.

2.4 DOCUMENT CONTROL

Today's litigious society would greatly benefit from implementation of a bar code system which tracks the myriad of documents associated with a construction contract. But, a system such as this should not be initiated for the sole purpose of justifying claims and lawsuits. Most importantly, a bar code system would help the owner's, contractor's and designer's representatives do a better job of managing the construction project. (Note : For the purposes of this discussion, documents will be defined as those shown in Table 4.) First, a bar code system would provide instant access to the location of a document and when it was received. Second, the same system can provide an up-to-date status on the action required by the document, can help formulate expected action durations for the planning purposes of all affected parties and can identify bottlenecks which require management intervention to overcome. The last point, concerning the bottlenecks, is perhaps the most important. In a large majority of the time, each party (OICC, Contractor and Designer) responds to action correspondence in such a timely fashion so as not to impact the progress of the job. It is when this responsibility is ignored that management must become involved. It is at this point that the AROICC assumes the greatest challenge - administration of the assigned construction contract and the monitoring of the support functions provided by the designer, whose contract has been

largely completed and under the administrative purview of another engineer. A bar code system which tracks the movement of documents will help the AROICC (who typically is assigned twenty to thirty projects at a time to administer) more quickly and accurately assess the progress of each project, allowing the individual to dedicate what little time is available toward the pressing issues of the day.

The first step in putting this system in place is the assignment of a unique number (and label) to each document. In general, the originator of the document should be responsible for affixing the bar code label and assigning the document number, though all parties should agree on the numbering system in place. Each type of document (ie; submittals, requests for proposals, etc.) should have its own numbering scheme. This will allow for easy sorting by type of document but more importantly, will allow the time to complete calculations to be performed more easily. After deciding on the numbering system, the document file contents must be created. At a minimum, each file should contain a document name, description and number, the number of pages in the document, the current holder of the document and the current status as well as estimated completion date. Other pertinent data fields may be inserted at the discretion of the user.

The benefits of utilizing a bar code system for document control are :

1) Improved efficiency of tracking system - Less time will be spent searching for the location of a document and more time spent on problem areas. This area can be especially important when it comes to ordering material, based on the installation schedule, but predicated on the receipt of an approved submittal.

2) Improved management of contract administration duties - The contractor, designer and OICC will have information at their fingertips which will readily assess individual employee performance, with an eye toward correction of deficiencies. Additionally, the system will provide the OICC with an up-to-date listing of approved submittals, for use in on-site inspection and progress payment review.

3) Elimination of paper and mail services to distribute informational document copies - For example, when the contractor mails a submittal to the designer, an information copy of the submittal is often sent to the OICC. Under the document control system, this additional copy would not be necessary since the system will inform the AROICC as to the delivery of the submittal to the designer. For the same reason, the

designer will not be required to mail an information copy to the contractor when forwarding the action copy to the OICC.

Though direct monetary savings may not be apparent, indirect savings will be accrued by all parties due to improved management of the project and rapid identification of potential problem areas.

The set-up of a document control system utilizing bar code technology will require the following items :

1) Selection of a suitable bar code material and marking method - Due to the large number of bar code labels to be used, the use of paper labels will reduce the operating cost of the system by allowing them to be marked by a dot matrix printer. Typically, this type of printer is readily available as a part of the existing PC structure.

2) Selection of a bar code reader - The administrative departments of each party (OICC, Designer, Contractor) will require a bar code reader. This bar code reader should be directly connected to the existing PC structure for quick data input. Also, the type of scanner should be flexible enough to accommodate a variety of label locations. For this

purpose, a wand type scanner is recommended. Lastly, a roaming PDT will be required by each party for use by actionees to input data on the documents which they possess. Data from the PDT can be downloaded into the office PC at the end of each workday.

3) Computer software compatible with the existing PC structure, if available - Pre-packaged software programs should be extensively investigated to determine their compatibility with other softwares as well as the degree in which it meets the user's requirements. If none are available, a software should be created based on the user's criteria. The prior comments regarding communication software remain valid.

4) PC requirements are the same as in the prior two sections, except that an additional PC is now required in the office of the designer.

1.) Request for Proposal

2.) Change Orders

3.) Claims

4.) Daily Reports

5.) General Correspondence

6.) Submittals -

- Shop Drawings
- Certificates of Conformance
- Test Reports
- Samples
- Requests for Deviation
- Other

Table 4

Typical Document Types

2.5 MATERIAL CONTROL

The use of bar code technology to monitor the receipt, control and issue of materials for a construction project will improve the efficiency of an important part of a contractor's operation. Bar code technology will accurately and quickly be able to inform the superintendent if the quantities of material necessary for a particular task are on site. Additionally, updated daily receipt records will enable the Federal Government's Construction Representative (CONREP) to inspect the material for contract/submittal compliance and reject that which does not meet the specification prior to installation. The performance of this simple act will save the contractor from expending unnecessary funds on corrective actions necessary due to the installation of unsatisfactory material.

To accommodate this process, a warehouse and secured outdoor storage area (for oversize items) will be required. All subcontractors will be required to store their material in this central location. A supply clerk, hired by the prime contractor, will be required to run the warehouse for all the companies working on the site. In establishing this set-up, two immediate benefits are derived :

1) Since the Federal Government will pay for material delivered and stored on the site prior to installation, the contractor will be encouraged to obtain approval

for and purchase materials in advance of their installation. The ability to request payment for these assets will improve the contractor's cash flow and reduce the amount of financing needed (the interest cost associated with the acquisition of financing is typically added to the bid price) to start the job.

2) Operation of the material function by a supply clerk will improve the efficiency and accountability of the system. The documentation of the receipt and issue of materials, the inspection of incoming material for quantity and damage and the purchase of consumable (bench stock) items before they run out will be only a few of the tasks the supply trained professional can accomplish. Additionally, the presence of this individual will minimize the amount of time necessary for the skilled worker to obtain material since the clerk will know the material's stock posture and, if on hand, its location, for timely issue.

What makes the use of bar coding in this operation logical is the increasing number of suppliers already using the technology (all suppliers of material to the Department of Defense are required to use bar codes) and the need for real time data on material availability for production planning.

To initiate this program, two data fields require development. First, the issue of how to handle material whether or not a bar code is attached. The process of receiving a bar coded material is easy. The bar code is simply scanned (the bar code contains unique data which identifies the item) to enter the material data and its status into the inventory field created for this purpose, and then moved to its storage location. If no bar code is attached, a menu board system, such as that shown in Figure 3, can be used with the inventory data field to enter the necessary information. Due to the large variety of material types necessary to construct a facility, a menu board for each CSI section should be fabricated (material delivered in place, such as concrete or asphalt, can be received by the supply clerk utilizing a menu board and a PDT as the truck enters the site). Use of a CSI section menu board will allow more detailed descriptions and enable the clerk to more quickly receive the shipment by not requiring the individual to search through hundreds of bar codes for the correct one. Second, the development of a location code structure for the warehouse and storage area should be fabricated. As material is received, its storage location can be inserted into the inventory data file for quick and easy material retrieval during the issue process. The location code structure should be kept as simple as possible (ie; storage row, bin or shelf number, zone number) for easy use.

The benefits of installing a bar code material control system are as follows :

1) Improved accountability for material received and issued results in more accurate progress payment requests submitted, reducing the administrative time required for OICC review and approval, due to the reliability of the bar code system data base.

2) Improved production efficiency due to real time receipt and issue records, which allow the CONREP to inspect the items for contract compliance, therefore eliminating the possibility of installing unsatisfactory materials and the cost of corrective action to remove them.

3) Improved material control efficiency due to the presence of the supply clerk and the improved productivity of skilled workers who spend less time searching for materials required to complete an assigned task and more time on the task.

4) Improved job planning due to the ability of the supply clerk to provide up-to-date information on current material inventory and material due in for use in formulating future construction schedules.

Through application of a bar coded material control system, the OICC should be able to more efficiently and effectively monitor the progress of the project, given real time data to identify potential problem ares for resolution. The contractor's operation should also become more efficient, since an early identification process for material problems is in place and more time is available both to the superintendent and the skilled workers to perform their assigned functions. An expected result of this improved contractor efficiency should be potentially lower bids for Federal Government construction projects.

In addition to the warehouse and supply clerk issues covered previously, the set-up of a material control system utilizing bar code technology requires the following :

1) A PDT, with belt holder, for the supply clerk to receive truck deliveries of placed materials, like concrete and asphalt. The PDT should be of the same type described in the Construction Equipment section.

2) A PC, with attached moving beam scanner and decoder, for supply clerk use in the warehouse.

3) Computer software compatible with the existing PC structure, if available. Many standard pre-packaged

softwares are available for this purpose and should be adequate for this construction material requirement.

2.6 ACQUISITION STRATEGY

Implementation of the bar code technology plan described in the previous four sections will require a creative approach. Given the unusual aspect of the plan, the two-step bidding process is recommended to evaluate both technical merit and cost.

The type of contract should be of a cost plus variety, which should provide ample incentive for contractor participation. Use of an award fee is recommended, with the determination of such tied to the performance of the bar code system. The basic contract should provide for construction services (as defined by separately prepared drawings and specification) and the necessary hardware, software, personnel training and in-service technical support to make the bar code system function based on the previous description. As an aside, the contract with the designer who provided the construction drawings and specification must be amended to include participation in the bar code system.

The construction project selected to experiment with the bar code technology should be rather simple, like a standard barracks or warehouse project. This will allow simplification, to a large degree, of the bar code applications due to the use of standard equipment and material. Location of this project should also be considered. To keep costs down, particularly those involved

with sending data by telephone line, the project location should be such that the OICC, designer and contractor's home office are in the immediate vicinity. Proximity to the local Engineering Field Division office would also be a plus, in anticipation of their direct involvement.

For the purposes of budgeting, Table 5 contains a list of the bar coding equipment needed with approximate costs. It is assumed that the OICC, designer and the contractor's home office already possess the compatible PCs and dot matrix printers necessary for system operation. Also, note that the estimated costs are towards the pessimistic end of the spectrum for safety's sake.

HARDWARE			
Item	U/I	Unit Cost ($)	Total Cost($)
		OICC	
Modem (2400 baud)	1	340	340
Scanner w/decoder	1	500	500
Cable	LS	500	500
		CONTRACTOR	
PC (80386 processor)	3	4,500	14,000
Slot scanner	1	550	550
PDT	4	880	3,520
Scanner w/decoder	3	500	1,500
Modem (2400 baud)	3	340	1,020
Identification Cards	100	500	500
Cable	LS	500	500
		DESIGNER	
Scanner w/decoder	1	500	500
Modem (2400 baud)	1	340	340
PDT	1	880	880

Table 5

Bar Code Equipment Costs

		SOFTWARE	
Bar Code Printing	3	300	900
Communication	3	300	900
System Application	1 pkg.	30,000/process	120,000
		TOTAL	146,450

(Note: Increased costs due to cost plus contract or amendment to designer's contract not included. Assuming a $10M project, conservative increase to construction cost 5-10 % and to design contract 1%)

Table 5

Bar Code Equipment Costs

(Continued)

CHAPTER 4

SUMMARY

The primary reason to implement bar code technology is to reduce the cost of data processing and to introduce a higher level of control over an operation. The manufacturing sector of United States industry has enthusiastically embraced this new technology. The construction sector has yet to complement the manufacturing sector's initiative industry wide, though a handful of contractors, like Fluor-Daniel and The George Hyman Construction Company, have tried to make bar coding work.

Many potential uses, which parallel in some degrees manufacturing sector use, exist for construction industry implementation. The potential uses of bar code technology in the construction industry can be categorized as Designer applications, Fabricator/Supplier applications and Construction Field applications.

Designer applications are comprised of the monitoring of design product flow, the tracking of drawing revisions and submittals, the execution of quantity take-offs and the incorporation of drawing notes. Fabricator/Supplier applications include control of availability of materials for production, the issue of tools and the receipt,

inventory and issue of products or materials. Finally, Construction Field applications are made up of field material receiving, control and inventory, tool and consumable material issue, timekeeping and cost engineering, purchasing and accounting, scheduling, office operations and construction equipment control.

Given the Federal Government's role in the development of bar code standards and their policy concerning bar code markings on Department of Defense supplies, it is logical that the Federal Government should have a role in the implementation of bar code technology by the construction industry. Accordingly, an implementation plan for NAVFAC, the Department of the Navy facility engineering arm, is proposed, covering the following four areas :
Labor Hours, Document Control, Construction Equipment Costs and Utilization and Material Control.

The methodology to execute the bar code plan was presented, as were suggested hardware and software requirements. Finally, an acquisition strategy followed, which covered the necessary contracting considerations, accompanied by a list of bar code hardware and software equipments with approximate costs.

CHAPTER 5

CONCLUSION

A detailed review of the current state of bar code technology implementation reflects growing acceptance of the technology by all major industries except construction. There are four possible reasons why construction companies are not implementing bar code technology in their operations :

1) Lack of Bar Coding Experience
2) Lack of Capital
3) Lack of Confidence in Bar Code Technology
4) Lack of Incentive to Implement Bar Code Technology

The lack of bar coding experience covers two areas : the buyer and the seller. The contractor, as the buyer, has many available options, or sellers, to choose from. With the explosion of bar code usage in the 1980's, so too has grown the bar code consulting and equipment manufacturing business. Typically, the seller is capable of training the buyer on the operation of the system. Given this opportunity to learn about bar coding, the lack of expertise cannot be a valid reason behind the construction industry's reluctance to accept bar coding into their operations.

The lack of capital regards the amount of cash necessary, up front, to acquire the necessary hardware, software, installation and training. Assuming that the contractor already owns the PCs necessary for system operation and referring to Table 5, the cost of acquiring the remaining material is negligible compared to the size of many of today's construction contracts. Additionally, if cash flow is a problem, the implementation of a bar code system may be phased in a manner similar to the four categories proposed under the previously outlined implementation plan.

The lack of confidence may be in part due to a belief that construction workers cannot adequately operate a bar code system or that bar code materials do not have the ability to withstand the rigors of a construction site environment. With the opportunity to obtain system training from an abundance of bar code sector companies and the similarity in educational background between construction workers and their counterparts in the manufacturing sector who operate bar code systems, perceived construction worker inability to operate a bar code system is not a valid excuse for failure to implement bar code technology. Concerning bar code label material characteristics, there are many available sources of material specifically created to withstand certain environmental conditions. This research has shown that it is actually quite easy to select a suitable material, given the efforts of the U. S. Army. It can be concluded that the

lack of materials suitable for construction use is not a valid obstacle to bar code implementation.

The fourth reason, lack of incentive, is certainly the only valid one of those listed. Since bar code system implementation will require some capital expenditure and a learning curve to operate, many contractors may feel that introduction of a state-of-the-art system would cause them to lose a competitive edge with their rivals, not to mention profits, over the short term. This type of thinking not only fails to consider the long term benefits to bar code implementation, but, I believe, is a primary reason why American construction contractors are losing in the world-wide competition with their Japanese and German counterparts. Another reason why the American construction industry has not fully involved itself with advanced technologies is the lack of Federal Government assistance, similar to that provided in Japan and Germany. Those two countries reward their companies with tax breaks, low interest loans and assistance in developing, marketing and patenting advanced technologies to encourage firms to take on the risks involved. Our country, however, has no such policy. Until it does, only very large contractors with deep pocketbooks, like Fluor-Daniel, Bechtel and George Hyman, will experiment with advanced technologies like bar coding, though their efforts have been small in scope.

The answer to the question " How do we get the construction industry to become active in advanced technology development ?" is increased Federal Government involvement. The last paragraph discussed the need for Federal Government programs to help the construction industry experiment with advanced technology while allowing them to remain locally, regionally, nationally or globally competitive. Another method that can be used is to foster development through implementation plans underwritten by the Federal Government, such as I have proposed. Not only will experience be gained, but the project will act as a demonstration for others that a particular technology can be implemented without sacrificing " the bottom line ".

In summary, bar code technology is an available tool which the American construction contractor must use to remain globally competitive. To implement this technology will require some patience and sacrifice, in the short term. Over the long term, bar coding will give the contractor an efficiency edge over the field. But the Federal Government must become interested in fostering an advanced technology explosion in the construction industry. One of the methods to do so would involve agency sponsored projects, such as the implementation plan that has been proposed.

RECOMMENDATIONS

1) The Federal Government should create a Construction Agency under the Department of Commerce, similar to that which exists in Japan and Germany, to assist construction contractors willing to implement advanced technologies with low or no interest financing, grants, tax breaks and assistance in marketing and patenting their achievements.

2) The Department of Defense, who already requires bar codes on all supplies accepted into their supply system, should develop an implementation plan for full use of bar code technology in all facility related functions. The Department of Defense should also develop a plan for the use of bar codes in the acquisition of construction and design services.

3) NAVFAC, as the Department of the Navy's construction services expert, should develop a pilot program, similar to that stated previously, to evaluate the effectiveness of bar coding in its construction program. The pilot program should look at both the potential improvement in the contractor's operation (as it relates to the elimination of contingencies and thus lower bids) as well as improvement in OICC operations.

4) Professional groups, like the American Society of Civil Engineers and the Construction Industry Institute, should actively pursue development of a construction industry program to promote the use of bar code technology. Also, these groups should pursue the implementation of a pilot program to evaluate bar code technology use.

5) Construction contractors should actively investigate the use of bar code technology as a means of improving the efficiency of their operation.

6) Bar Code Technology Manufacturers should direct themselves toward developing products specifically oriented to construction use.

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